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Report on forest cover change from 1993/94 – 1999/2000 for two forest corridors in eastern Madagascar

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Introduction

This forest cover change detection study was carried out to determine the rate of change in forest cover for two selected USAID priority zones. The northern zone included the forest corridor between Mantadia and Zahamena and the southern corridor included the forest corridor between Ranomatana and Andringitra. The study area was defined, by the consultant, using the satellite imagery and an overlay of protected areas. No other ancillary information was provided so this study area may not match other delineations used by USAID. See figure 1 for the location of the corridors. The time period for the study was to coincide with the

Description of the data sets used

Landsat Thematic Mapper (TM) data, with a spatial resolution of 28.5 meters, were used for both dates for the northern corridor. For the southern corridor, TM data were used for the recent date and Landsat Multispectral Scanner (MSS) data, with a spatial resolution of 80 meters but resampled to 60m were used for the historic date. The lower resolution MSS data were used because suitable TM data could not be ordered in time. Incorporating the MSS data in this study certainly reduced the accuracy but it was the best available data given the timeframe of this study. Information about the satellite images is presented in table 1.

Table 1 Satellite image information

Location Description	Acquisition Date	Path/Row	Satellite (resolution)
Zahamana	8-April-1993	158 / 72	Landsat TM (28.5m)
Zahamana	19-April-2000	158 / 72	Landsat TM (28.5m)
Mantadia	21-November-1994	158 / 73	Landsat TM (28.5m)
Mantadia	19-April-2000	158 / 73	Landsat TM (28.5m)
East side of southern corridor	30-August-1993	158 / 75	Landsat MSS (80m)
East side of southern corridor	11-November-1999	158 / 75	Landsat TM (28.5m)
West side of southern corridor	6-September-1993	159 / 75	Landsat MSS (80m)
West side of southern corridor	17-October-1999	159 / 75	Landsat TM (28.5m)

All of the 1999 and 2000 images were ortho-rectified with a published accuracy of 50 meters root mean square error (RMSE) or better. The other images had only systematic corrections applied. This created problems of co-registration because it was not practical to ortho-rectify the 1993/94 images and therefore only simple image warping using control points could be done to register the two data sets. This is described in more detail in the methods section.

Methods

For this study, forest was loosely defined as an area of tree greater than 7 meters in height with greater than 30% crown closure. Since no ground verification data were available this definition of forest was loosely applied using visual methods based on the experience of the consultant. Only two classes were used, forest and non-forest. With no ancillary data it was impractical to expect sufficient accuracy if more classes (such as secondary forest) were used. Due to the relatively short period between the two time periods used in this study the only change classes identified were; forest to forest, non-forest to non-forest, forest-to-non-forest, and obscured. The change class non-forest-to-forest was not identified because it was presumed that detection of such a class could not be done reliably and from the consultants experience it was unlikely that a significant area of that class was present. The “obscured” class included areas that were covered by clouds or shadows. Obscured areas were not used during the analysis.

The software package used for all processing and visualization was ENVI (Research Systems, Boulder, Colorado). ENVI is a powerful image processing system with the capability to carry out all of the tasks necessary for this study.

Two types of images were created during this study. The first was a forest cover image that was used to provide the area covered by forest within the two study areas during the 1993/94 time period. The other image was a change image that showed the areas that changed from forest-to–non-forest. Although it is possible (and sometimes preferred) to only create a change image since that provides the four change classes (forest to forest, non-forest to non-forest, forest-to-non-forest, and obscured) it was decided that a more accurate result could be provided given the restricted time available for analysis using the forest cover and forest change images. The train of thought used for this decision was that a more accurate classification of forest cover could be determined using a single date image and the change class of forest-to-non-forest could more easily and accurately be delineated if that was the only class of interest using the multi-date image.

The forest cover map was created with supervised classification methods using the TM images acquired in 1999/2000. These images were used because of their high quality. To calculate forest cover for the 1993/94 time period the area of the change class forest-to-non-forest was added to the forest cover class for each image location.

To create the forest image a series of training areas (samples from the satellite image) representing the forest, non-forest, and obscured classes were delineated visually. Next, these training areas were input into a maximum likelihood algorithm (MLC) and the output from this was an image of forest, non-forest, and obscured. The accuracy of the forest estimate is probably on the order of +/- 10 percent at a 95% confidence level. This estimate is based solely on the consultants experience and not on a reliable assessment of accuracy.

The creation of the forest cover change image was carried out in several steps. The steps were:

- Preprocess the images to create image pairs
- Select training sites and run a supervised classification
- Eliminate all pixel clusters with less than 9 pixels
- Update the obscured class to only include pixels visible on both dates
- Mosaic the change and forest images for each corridor
- Calculate statistics and output the results

Preprocess the images

Before the analysis could be started the images had to be preprocessed to put them into the Oblique Mercator projection that is used throughout Madagascar and to co-register them to minimize image-to-image offsets. The 1999 and 2000 images were used as the reference images since they had been ortho-rectified and they had acceptable errors. The early-date images (1993/94) were registered to the 1999/2000 images by selecting points that could be seen on both images and then warping the early-date image to fit the late-date image. Second degree polynomial warping was applied. This resulted in a moderately good image-to-image fit but the positional errors were greater than one would hope for with this type of study. These errors resulted because the 1999/2000 images were corrected using 3-dimensional data (a digital elevation model) followed by a non-linear projection (UTM to Oblique Mercator) and the warping process employed by the consultant used only 2-dimensional data. A solution to this problem would have been to have the early date images ortho-rectified using the same procedure used for the late-date images but this was not possible given the time restraints of the project.

The images from the two dates for each location (path/row) were then combined into one multi-date image. For example, when the two images were both TM image the resulting image had 12 bands; 6 bands from the early date image and 6 bands from the late date image. Only TM bands 1,2,3,4,5,7 were used. This resulted in 4 multi-date images, one for each path / row location. For the TM/MSS combination the MSS data were resampled to a pixel size of 28.5 meters using a nearest neighbor resampling. Since the MSS images only have four bands, the resulting multi-date image had 10 bands (6 from the TM image and 4 from the MSS image).

Select training sites and run supervised classification

Standard supervised classification methods were used to classify the different change classes. Training sites are regions (generally with 100 or more pixels) on the satellite image that represent a particular class such as forest-to-forest. The training sites are used to generate statistics that are used to identify all of the pixels in the image. For example, a training site is selected to represent the forest-to-forest and then statistics from that training site is used to identify other forest-to-forest pixels in the satellite image. Once enough training sites are selected to adequately represent the classes one wants to generate, an algorithm is run to classify each pixel in the satellite image.

After a run, the results were inspected and then if necessary training sites were added or removed and the classification algorithm was re-run. This process was repeated until an acceptable result was obtained. The result of the supervised classification was an image with each pixel classified as one of the change classes.

At the beginning of this study it was envisaged that the consultant would visually inspect the classification and then manually modify the forest-to-non-forest class to correct classification errors. Unfortunately, there was not sufficient time to do this for the two corridors and so no adjustments were made to the automated classification results.

Eliminate small pixel clusters

Because of errors inherent with this kind of satellite image analysis it is a common practice to post-process the classified image by removing small clusters of pixels that likely are a result of misclassificaation. A common cause of these errors comes from the fact that the images are not perfectly co-registered. For this study, an algorithm was used that eliminated any group with 9 or fewer connected pixels. The algorithm considered 8-neighboring pixels (pixels directly above, below, left of, right of, and off the corners) to determine if one pixel was connected to another.

Update the obscured class

The obscured classes for the forest cover image and the forest change image were updated to be identical for both images. This was done by combining the obscured classes from the forest and forest change images and then replacing the original obscured class with the combined class. This assured that only those pixels not classified as obscured in either the forest map or the change map were included in the analysis.

Mosaic images

After the classification results were finished, the images within a corridor were mosaiced to create a continuous image for each corridor. Unfortunately, the northern portion of the southern image for the Zahamena – Mantadia corridor was truncated which resulted in a gap between the northern and southern images. This gap is obvious in Figure 1. In the Ranomafana – Andringitra corridor there was significant overlap between the two images and a decision was made by the consultant to have the eastern image take precedence over the western image during the mosaic processing. In other words, in the overlap portion of the mosaic the eastern image covered the western image.

Calculate statistics

The last step was to calculate statistics for each corridor. Since the time periods between the early and late-date images was different for each image pair a mask was created to identify which image was used to create the mosaic. This allowed statistics for each image pair to be calculated by overlaying the forest cover and forest change images with the respective masks. Statistics were also calculated for the east and west sides of each corridor using a mask created by visually approximating a north-south centerline through each corridor.

The following formula was used to calculate the rate of change from forest to non-forest:
For each image calculate:

% Forest loss = Forest loss / Forest T1 * 100

Annual forest loss = % Forest loss / ((2nd date - 1st date[in days]) / 365)

Weighted % annual loss = Annual forest loss * (Forest T1 / Sum of Forest T1 for both images)

For the average forest loss for the corridor:

Average annual forest loss = Sum of the weighted % annual loss for both images

Note: T1 is the early date

Results

The results from this study are presented in tables 2 through 7. The accuracy of the results for this study could not be evaluated using reliable methods. This was due primarily to time constraints. Using the consultant's experience, however, it is expected that the results for the northern corridor (Zahamena – Mantadia) are better than +/- 15% at a 95% confidence interval. For the southern corridor (Ranomafana – Andringitra) the errors are estimated to be better than +/- 20% at a 95% confidence interval. The lower accuracy for the southern corridor is from combining TM and MSS data. It is suggested that this study be continued in order to validate and improve these results.

Table 2 Zahamena – Mantadia corridor summary

NF => NF Km^2	F => F Km^2	F => NF Km^2	Obscured Km^2	Total F => NF	F => NF rate/year
3,287.39	4,873.51	108.56	364.06	2.18%	0.36%

Table 3 Zahamena – Mantadia western side of corridor

NF => NF Km^2	F => F Km^2	F => NF Km^2	Obscured Km^2	Total F => NF	F => NF rate/year
1,487.70	2,741.71	56.14	56.96	2.01%	0.32%

Table 4 Zahamena – Mantadia eastern side of corridor

NF => NF Km^2	F => F Km^2	F => NF Km^2	Obscured Km^2	Total F => NF	F => NF rate/year
1,799.69	2,131.80	52.41	307.10	2.40%	0.41%

Table 5 Ranomafana – Andringitra corridor summary

NF => NF Km^2	F => F Km^2	F => NF Km^2	Obscured Km^2	Total F => NF	F => NF rate/year
2,589.96	2,158.98	78.70	1,049.19	3.52%	0.57%

Table 6 Ranomafana – Andringitra western side of corridor

NF => NF Km^2	F => F Km^2	F => NF Km^2	Obscured Km^2	Total F => NF	F => NF rate/year
1,575.27	1,268.29	36.46	425.69	2.79%	0.45%

Table 7 Ranomafana – Andringitra eastern side of corridor

NF => NF Km^2	F => F Km^2	F => NF Km^2	Obscured Km^2	Total F => NF	F => NF rate/year
1,014.70	890.69	42.24	623.50	4.53%	0.83%

Conclusion

The results from this study provide rates of deforestation for two corridors in Madagascar. The methods used for the satellite interpretation portion of this study are sound and can be implemented using one of several different image-processing packages. There are several different options available for classifying satellite images into forest cover change classes. The methods used for this study were selected primarily because of the time limitations imposed on this project. If more time were available other methods would have likely been used. More important than the classification method, however, is the validation of the classification results. If higher accuracy estimates are necessary, it is imperative that a reliable field verification phase be conducted. The lack of such a component in this study significantly degraded the accuracy of the results.

The results from this study should be considered preliminary and an effort should be made to improve upon the work already completed.

Figure 1: Forest cover change study areas